US009450607B1

(12) **United States Patent**
Alakuijala et al.

(10) **Patent No.: US 9,450,607 B1**
(45) **Date of Patent: Sep. 20, 2016**

(54) ENCODING OR DECODING CHARACTERS AS WORD IN CORPUS

(71) Applicant: **GOOGLE INC.**, Mountain View, CA (US)

(72) Inventors: **Jyrki Antero Alakuijala**, Adliswil (CH); **Zoltan Szabadka**, Adliswil (CH)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 236 days.

(21) Appl. No.: **14/328,010**

(22) Filed: **Jul. 10, 2014**

(51) **Int. Cl.**
H03M 7/30 (2006.01)
G06F 17/22 (2006.01)
G06F 17/27 (2006.01)

(52) **U.S. Cl.**
CPC *H03M 7/3086* (2013.01); *G06F 17/2217* (2013.01); *G06F 17/2276* (2013.01); *G06F 17/2735* (2013.01); *H03M 7/3088* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,951,623 A *	9/1999	Reynar	H03M 7/3086 341/106
7,026,962 B1 *	4/2006	Emami	H03M 7/3088 341/106
8,044,829 B2 *	10/2011	Chen	H03M 7/3086 341/51

OTHER PUBLICATIONS

"LZ77 and LZ78", from Wikipedia, the free encyclopedia, May 21, 2014, 4 pages.

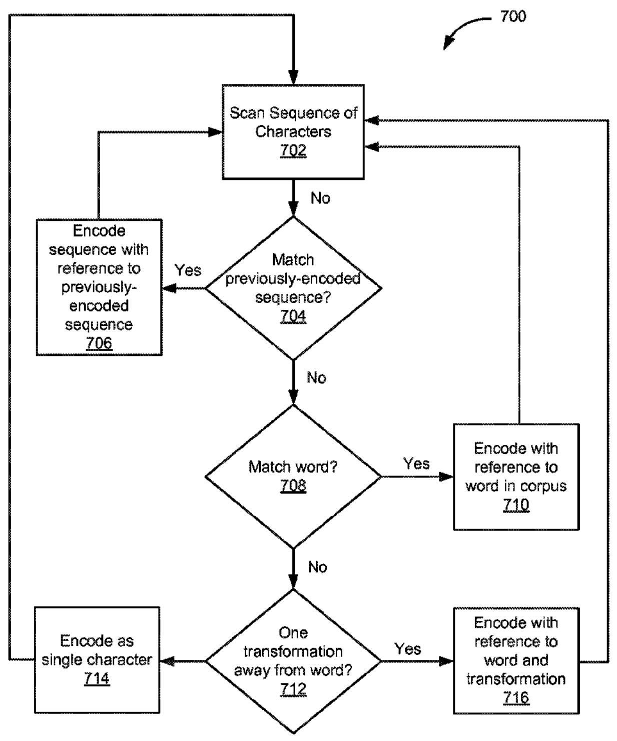
* cited by examiner

Primary Examiner — Howard Williams
(74) *Attorney, Agent, or Firm* — Brake Hughes Bellermann LLP

(57) **ABSTRACT**

Data may be decompressed by receiving a compressed sequence of characters, the compressed sequence of characters being represented by at least a first received number, dividing the first received number by a number of words in a corpus of words to determine a quotient and a remainder, retrieving a word from the corpus of words based on the remainder, retrieving a transformation from a transformation index based on the quotient, and performing the retrieved transformation on the retrieved word. The representations of characters included in the transformed word may be a decompressed version of the received compressed sequence of characters.

25 Claims, 10 Drawing Sheets


700
Scan Sequence of Characters 702
No
Match previously-encoded sequence? 704
Yes
Encode sequence with reference to previously-encoded sequence 706
No
Match word? 708
Yes
Encode with reference to word in corpus 710
No
One transformation away from word? 712
Yes
Encode with reference to word and transformation 716
Encode as single character 714

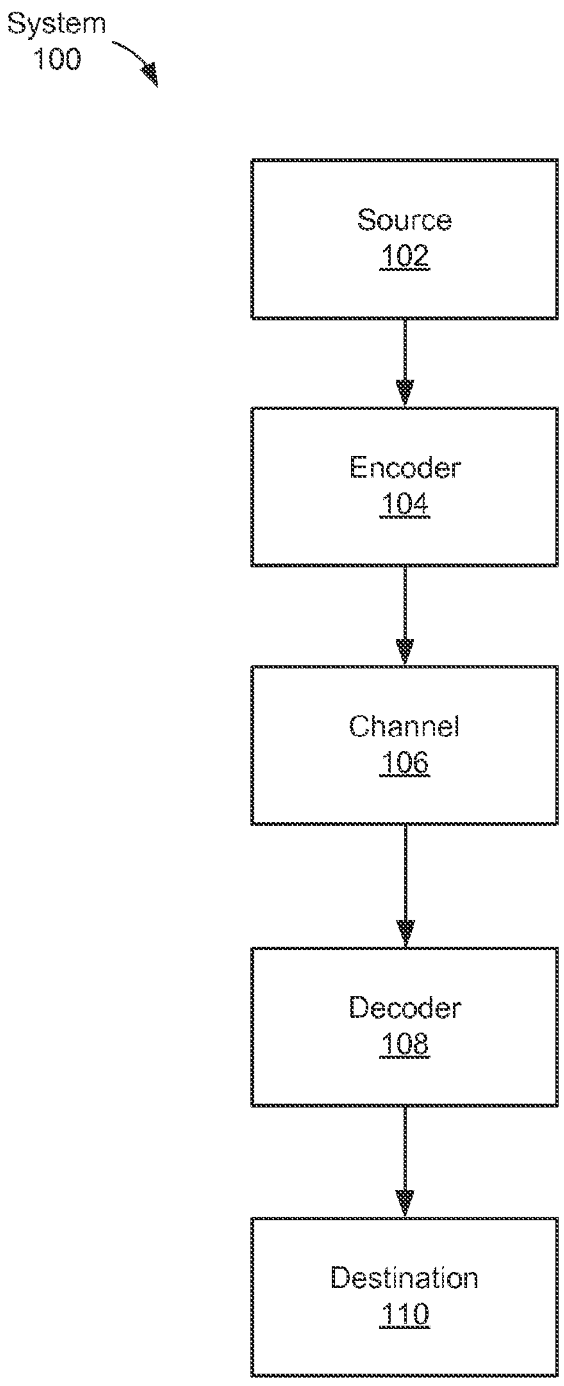

System
100
Source
102
Encoder
104
Channel
106
Decoder
108
Destination
110

FIG. 1

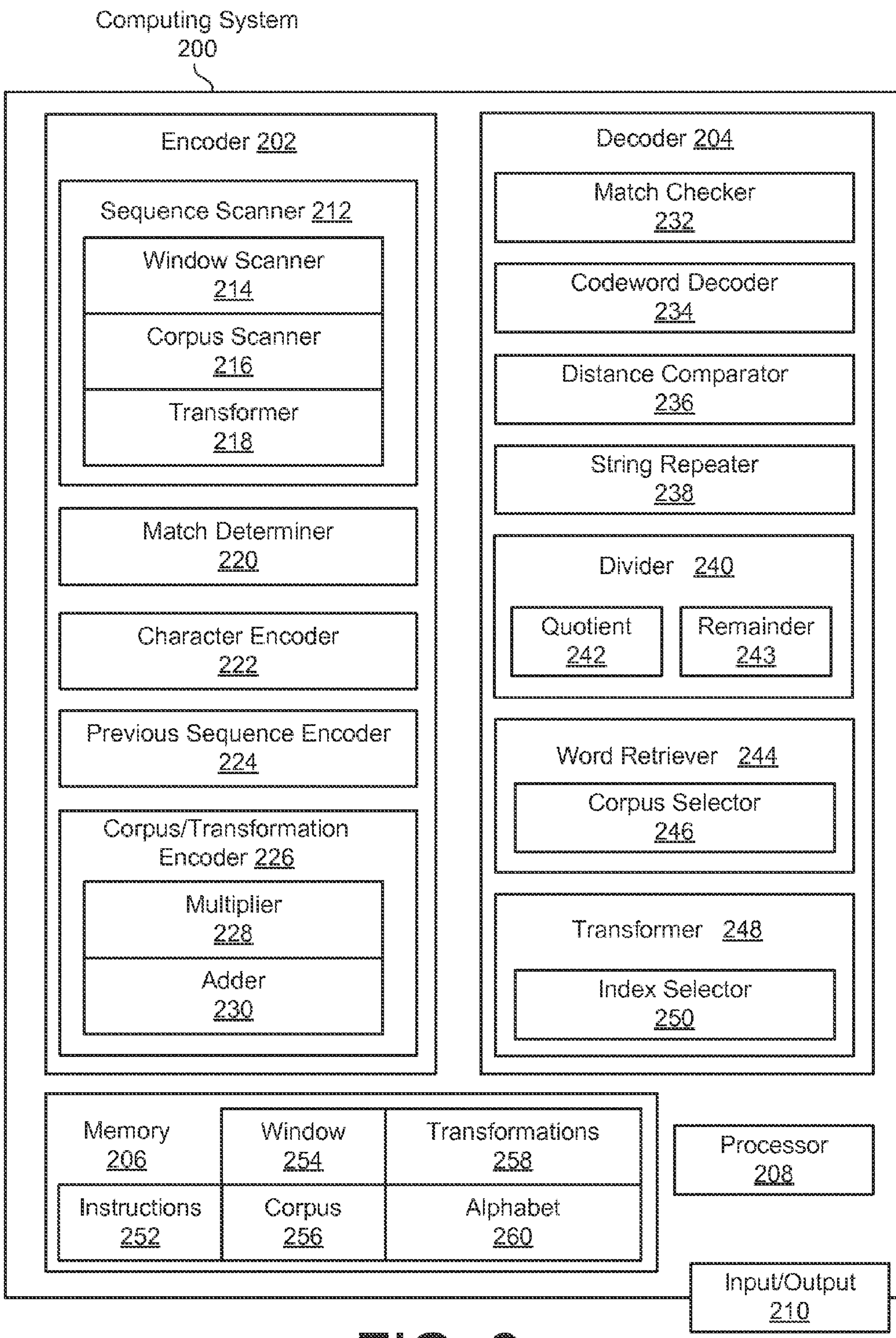

Computing System
200
Encoder 202
Sequence Scanner 212
Window Scanner
214
Corpus Scanner
216
Transformer
218
Match Determiner
220
Character Encoder
222
Previous Sequence Encoder
224
Corpus/Transformation
Encoder 226
Multiplier
228
Adder
230
Decoder 204
Match Checker
232
Codeword Decoder
234
Distance Comparator
236
String Repeater
238
Divider 240
Quotient
242
Remainder
243
Word Retriever 244
Corpus Selector
246
Transformer 248
Index Selector
250
Memory
206
Window
254
Transformations
258
Instructions
252
Corpus
256
Alphabet
260
Processor
208
Input/Output
210

FIG. 2

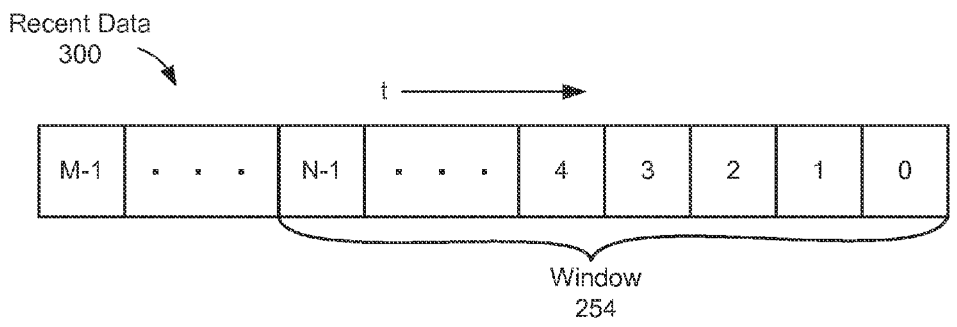


FIG. 3A

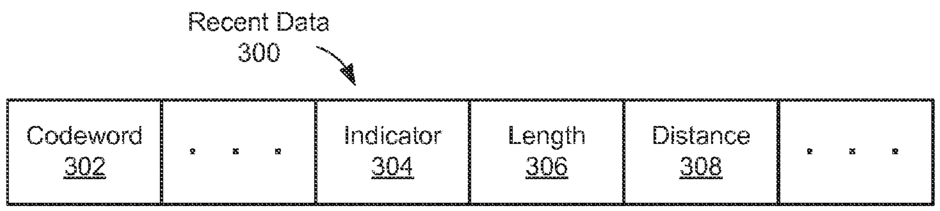


FIG. 3B

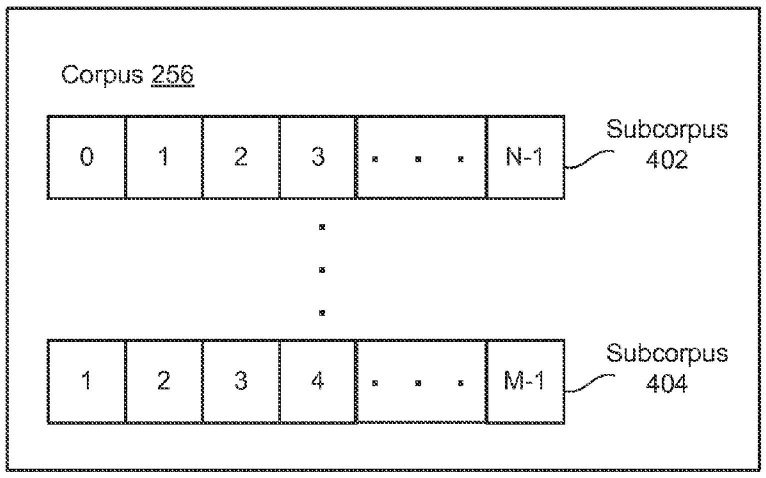


FIG. 4

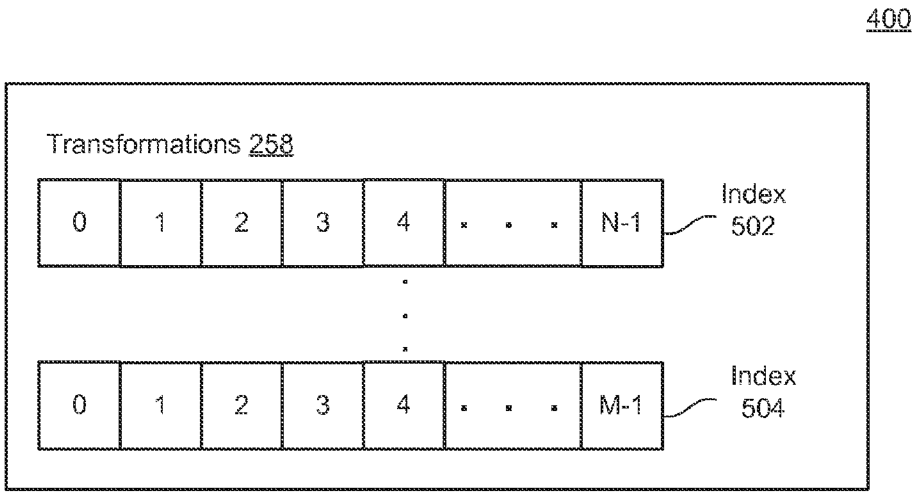

400
Transformations 258
0
1
2
3
4
N-1
Index 502
0
1
2
3
4
M-1
Index 504

FIG. 5

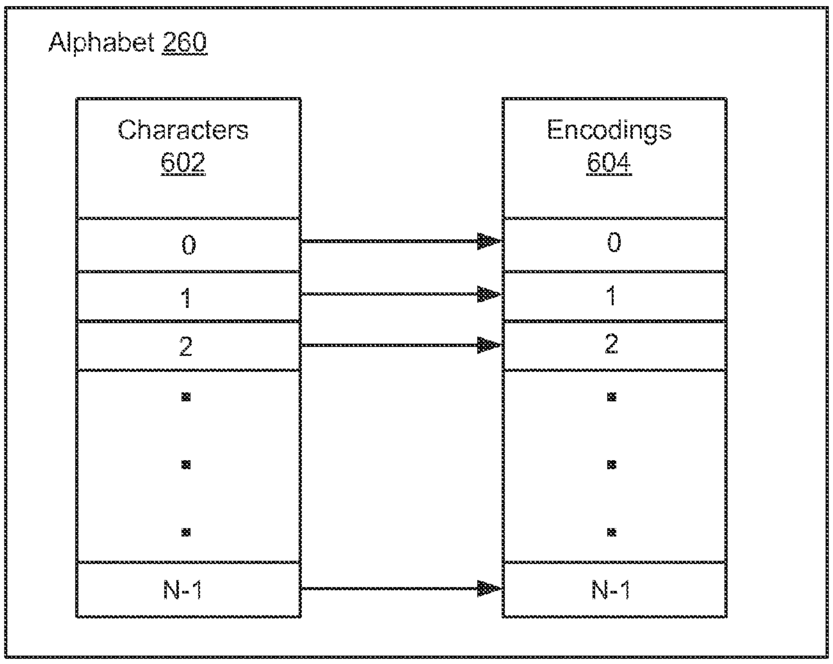

Alphabet 260
Characters 602
Encodings 604
0
1
2
N-1
0
1
2
N-1

FIG. 6

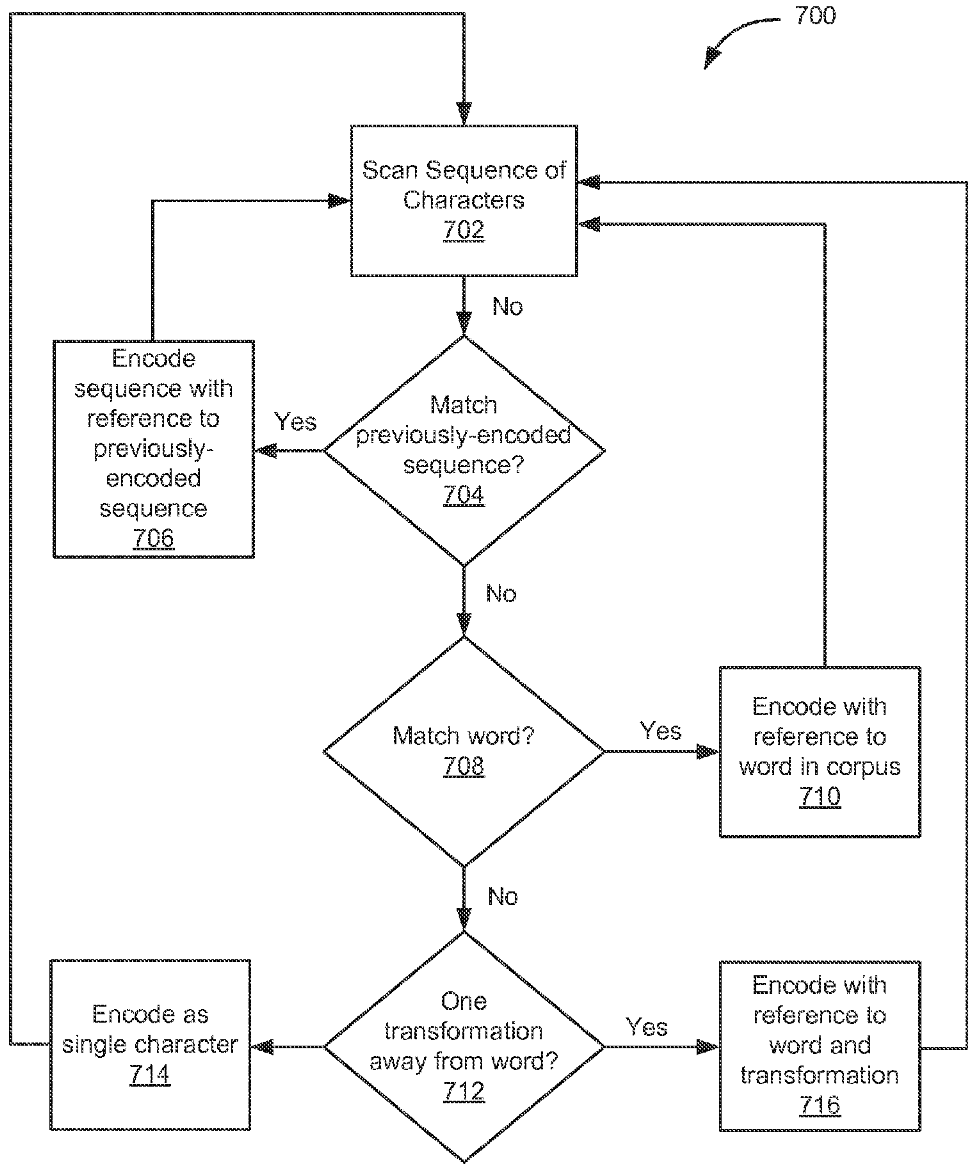

700
Scan Sequence of Characters 702
No
Match previously-encoded sequence? 704
Yes
Encode sequence with reference to previously-encoded sequence 706
No
Match word? 708
Yes
Encode with reference to word in corpus 710
No
One transformation away from word? 712
Yes
Encode with reference to word and transformation 716
Encode as single character 714

FIG. 7

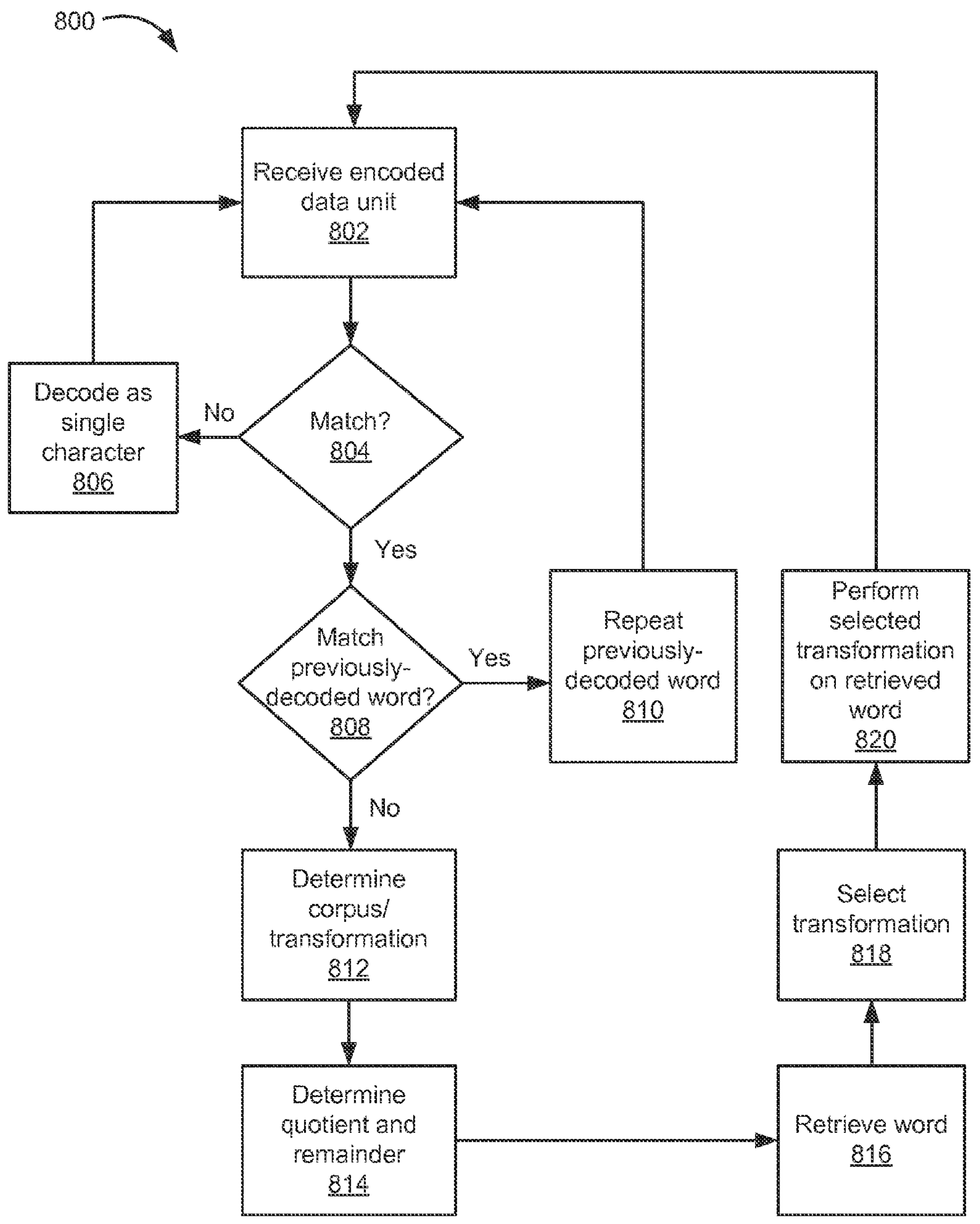

800
Receive encoded data unit 802
Match? 804
No
Decode as single character 806
Yes
Match previously-decoded word? 808
Yes
Repeat previously-decoded word 810
No
Determine corpus/ transformation 812
Determine quotient and remainder 814
Retrieve word 816
Select transformation 818
Perform selected transformation on retrieved word 820

FIG. 8

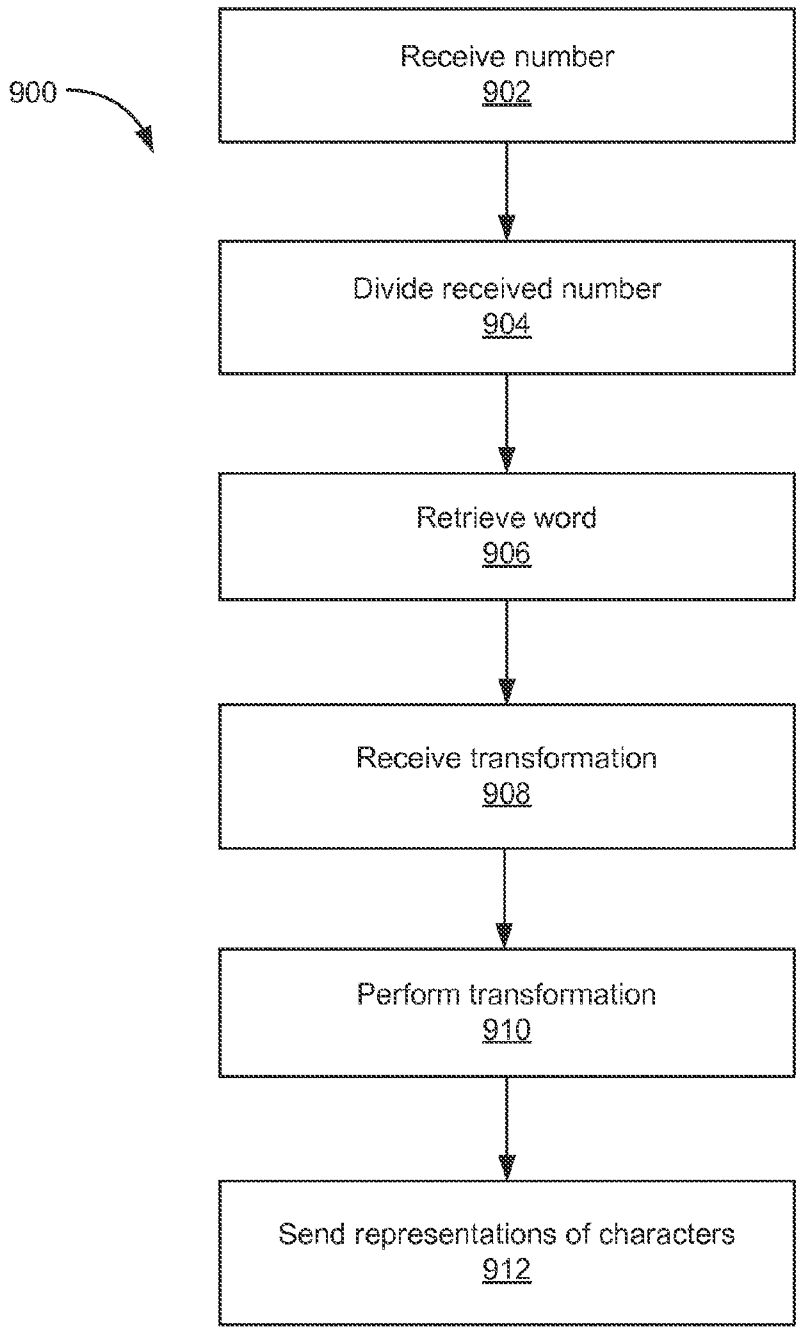

900
Receive number
902
Divide received number
904
Retrieve word
906
Receive transformation
908
Perform transformation
910
Send representations of characters
912

FIG. 9

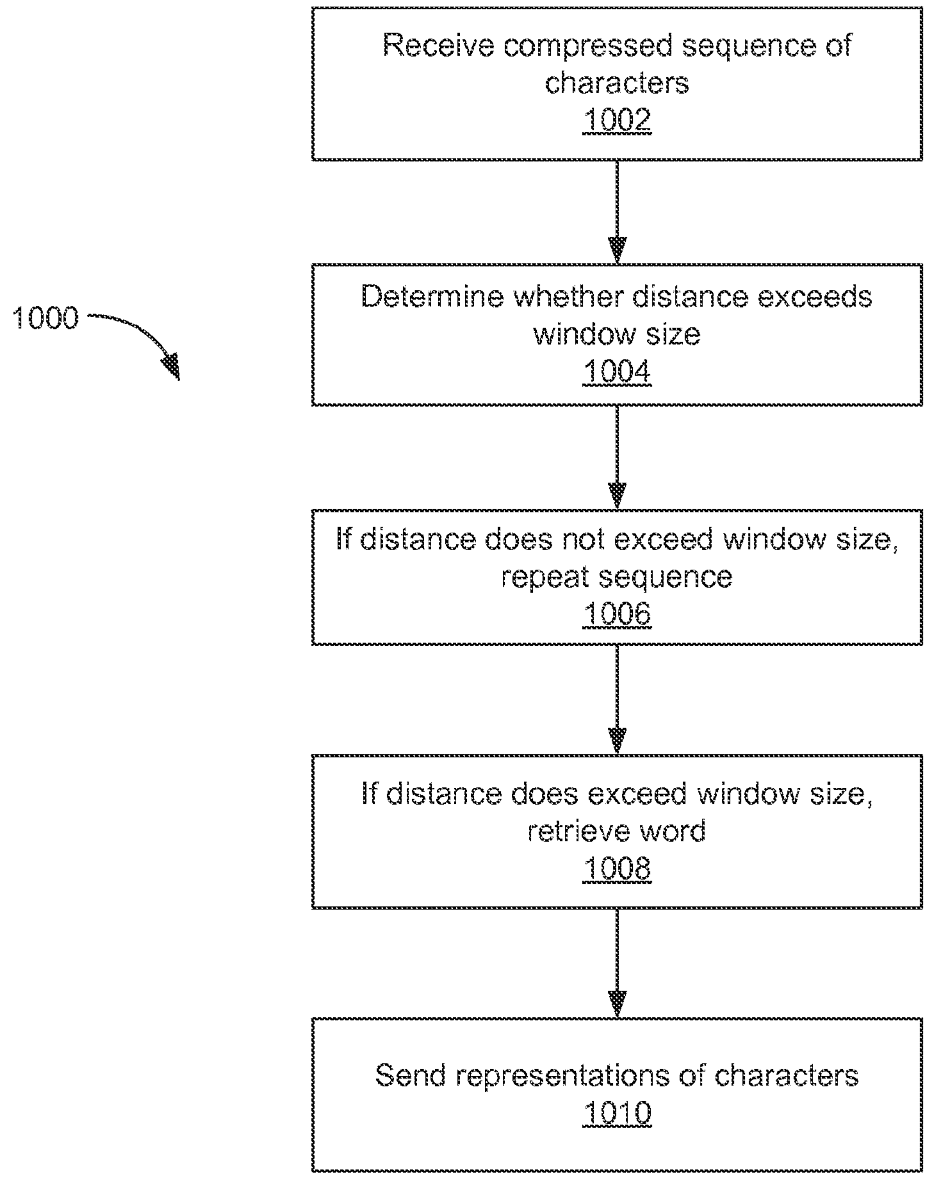

1000
Receive compressed sequence of characters
1002
Determine whether distance exceeds window size
1004
If distance does not exceed window size, repeat sequence
1006
If distance does exceed window size, retrieve word
1008
Send representations of characters
1010

FIG. 10

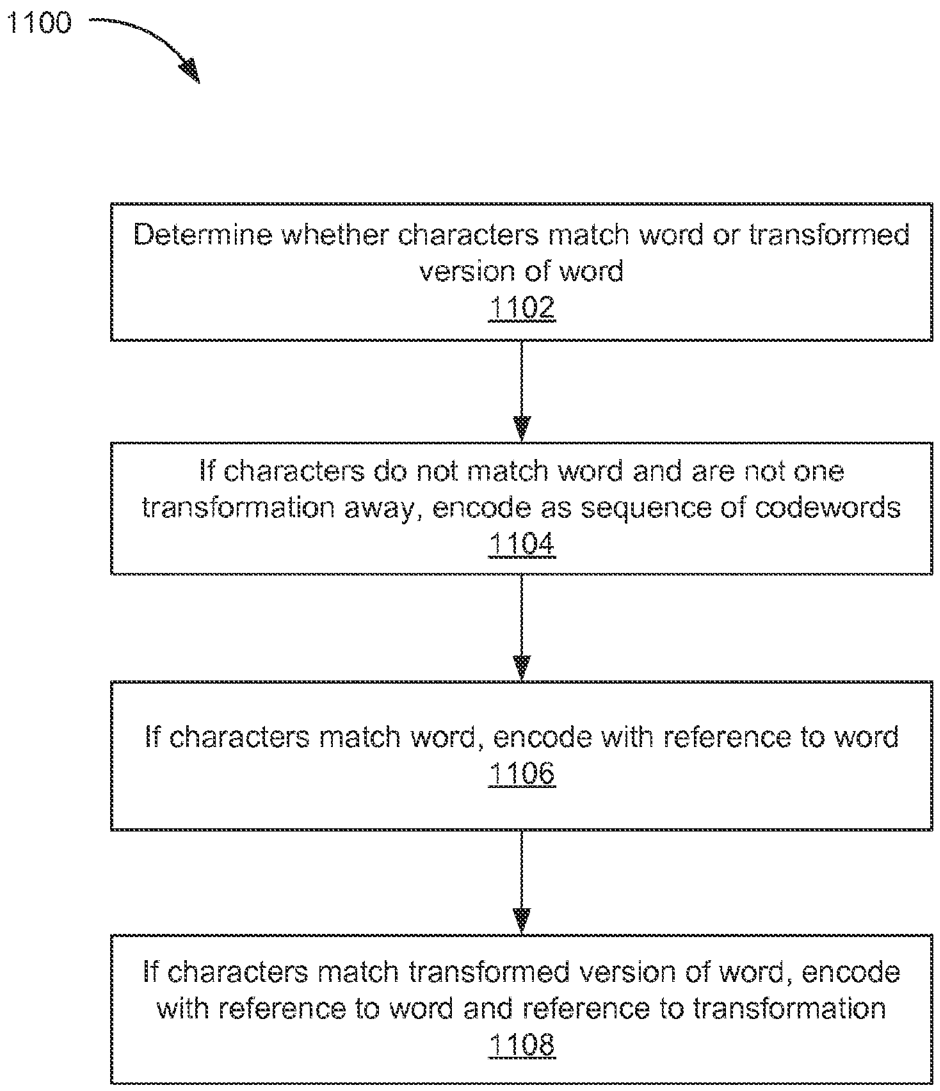
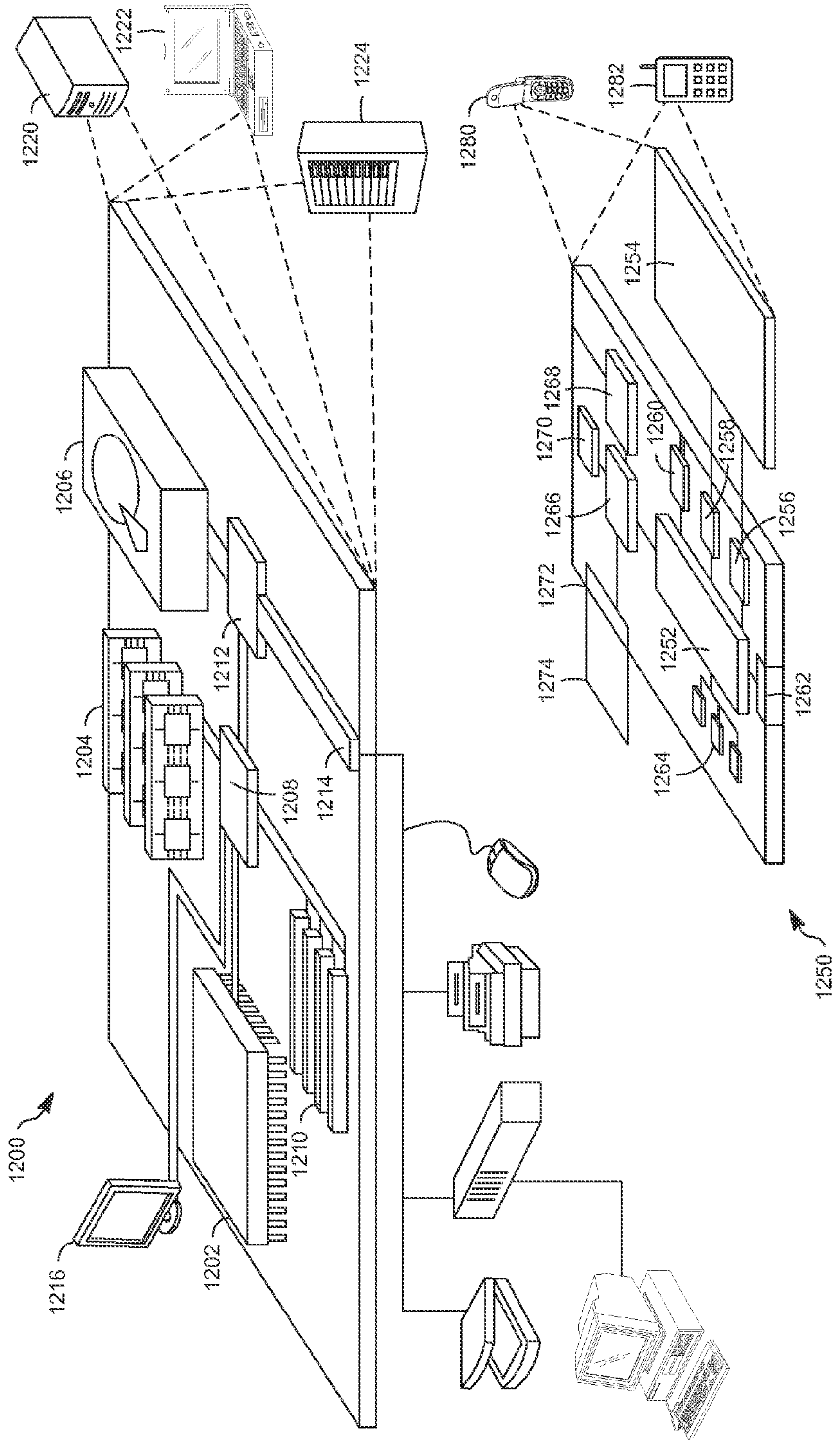

1100
Determine whether characters match word or transformed version of word
1102
If characters do not match word and are not one transformation away, encode as sequence of codewords
1104
If characters match word, encode with reference to word
1106
If characters match transformed version of word, encode with reference to word and reference to transformation
1108

FIG. 11

FIG. 12


1200
1202
1204
1206
1208
1210
1212
1214
1216
1220
1222
1224
1250
1252
1254
1256
1258
1260
1262
1264
1266
1268
1270
1272
1274
1280
1282

ENCODING OR DECODING CHARACTERS AS WORD IN CORPUS

TECHNICAL FIELD

This description relates to compressing and decompressing data.

BACKGROUND

Data may be compressed according to algorithms known to both sender and receiver. Compression may reduce the number of bits or other representations required to transmit the data.

SUMMARY

According to an example embodiment, a non-transitory computer-readable storage medium may comprise instructions stored thereon. When executed by at least one processor, the instructions may be configured to cause a computing system to decompress data by receiving, via an electronic transmission medium, a compressed sequence of characters, the compressed sequence of characters being represented by at least a first received number, dividing the first received number by a number of words in a corpus of words to determine a quotient and a remainder, retrieving a word from the corpus of words based on the remainder, the corpus of words being stored on at least one memory device, retrieving a transformation from a transformation index based on the quotient, the transformation index being stored on the at least one memory device, performing the retrieved transformation on the retrieved word, and sending representations of characters included the transformed word to a computing device, the representations of characters included in the transformed word being a decompressed version of the received compressed sequence of characters.

According to another example embodiment, a non-transitory computer-readable storage medium may comprise instructions stored thereon. When executed by at least one processor, the instructions may be configured to cause a computing system to decompress data by receiving, via an electronic transmission medium, a compressed sequence of characters, the compressed sequence of characters being represented by at least a distance value and a length value, determining whether the distance value exceeds a window size of a window of previously decoded characters, the window of previously decoded characters being stored on at least one memory device. If the distance value does not exceed the window size, the instructions may be configured to cause the computing system to repeat a sequence of previously decoded characters from the window of previously decoded characters with a length based on the length value at a position in the window of previously decoded characters based on the distance value. If the distance value does exceed the window size, the instructions may be configured to cause the computing system to retrieve a word from a corpus of words, the corpus of words being stored on the at least one memory device. The instructions may be further configured to cause the computing system to send representations of characters included in the retrieved word to a computing device, the representations of characters included in the retrieved word being a decompressed version of the received compressed sequence of characters.

According to another example embodiment, a non-transitory computer-readable storage medium may comprise instructions stored thereon. When executed by at least one

processor, the instructions may be configured to cause a computing system to compress data by determining whether a sequence of characters matches a word included in a corpus of words or matches a transformed version of the word, the corpus of words being stored in at least one memory device and the transformation performed on the word being stored in the at least one memory device. If the sequence if characters does not match the word included in the corpus of words and is not one transformation away from the word, the instructions may be configured to cause the computing system to encode the sequence of characters as a sequence of codewords. If the sequence of characters matches the word included in the corpus of words, the instructions may be configured to cause the computing system to encode the sequence of characters with a reference to the word. If the sequence of characters matches the transformed version of the word, the instructions may be configured to cause the computing system to encode the sequence of characters with a reference to the word and a reference to the transformation.

The details of one or more implementations are set forth in the accompa-nying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram of a communication system according to an example implementation.

FIG. **2** is a diagram of a computing system according to an example implementation.

FIG. **3**A is a diagram showing recent data and a window.

FIG. **3**B is a diagram showing encoded data according to an example implementation.

FIG. **4** shows a corpus of words according to an example implementation.

FIG. **5** shows an example of stored transformations.

FIG. **6** shows an example of a stored alphabet mapping characters to encodings.

FIG. **7** is a flowchart showing a method for encoding data according to an example implementation.

FIG. **8** is a flowchart showing a method for decoding data according to an example implementation.

FIG. **9** is a flowchart showing a method according to an example implementation.

FIG. **10** is a flowchart showing a method according to an example implementation.

FIG. **11** is a flowchart showing a method according to an example implementation.

FIG. **12** shows an example of a generic computer device and a generic mobile computer device, which may be used with the techniques described herein.

DETAILED DESCRIPTION

FIG. **1** is a diagram of a communication system **100** according to an example implementation. The communication system **100** may transmit information and/or data from a source **102** to a destination **110**. The information and/or data may represent characters, such as letters, numbers, punctuations marks, and/or symbols, in any language, such as English, German, Hungarian, Arabic, and/or Chinese. The characters may be encoded into a bit-level (ones and zeroes) or other representation, with combinations of multiple bits or other symbols representing characters, and may be compressed. Compression may reduce the number of bits or other symbols needed to represent the information and/or data.

The information and/or data may be compressed by, for example, including references to words and/or transformations. Rather than representing each character individually with a combination of bits or other symbols, some sequences of characters may be represented by references to words, or sequences of characters stored in a corpus or dictionary, and/or transformations, which may be modifications of or changes to the words. The words may be stored sequences of multiple characters, such as at least two characters, at least three characters, at least four characters, or any minimum number of characters. The minimum number of characters should be low enough to include a large number of words to facilitate encoding, but high enough that encoding by a length/distance pair requires fewer bits or other symbols than simply encoding each character individually.

The transformations may include, for example, an addition of a space (" ") before or after the word, capitalization of a first character of the word, addition of and/or prepending a prefix before and/or to the word, addition of and/or appending a period or suffix after and/or to the word, addition of a space and a common word (e.g. "the") after the word, or a change of font (e.g. italicization) of the word. Including suffixes, rather than prefixes (and/or but not prefixes) in the transformations, may facilitate determining whether a transformed word ends with a most recent character. The references to words and/or transformations may reduce the number of bits or other symbols needed to represent the information and/or data. Some sequences of characters may also be represented by references to previous sequences of characters, further reducing the number of bits or other symbols needed to represent the information and/or data.

An example index of transformations is appended hereto as Appendix A. In the example of Appendix A, a first column may include prefixes for which the transformation includes prepending the character(s) (if any) to the retrieved word, a second column includes transformations that include changing the characters in the retrieved word such as changing case or capitalization (such as from lower case to upper case or upper case to lower case) or removing a character, and a third column includes suffixes for which the transformation includes appending the (character(s) if any to the retrieved word. An ID of the transformation, which may range from 0 to 105 in the example shown in Appendix A, may be used to index the transformation. The quotient determined by dividing the distance value by the number of words in the corpus and/or subcorpus may directly index the ID of the transformation, or a remainder determined by dividing the quotient by the number of transformations (e.g. 105+1=106 transformations) may be used to index the ID of the transformation.

The system **100** may include the source **102**. The source **102** may include a computing system, or a component of a computing system such as a memory or a file, which stores information or data that represent characters, such as alphanumeric characters, punctuation marks, or characters or symbols according to any understood character system and/or language. The source **102** may, in response to an instruction or as part of an operation or function to transmit the information or data, provide the data or characters to an encoder **104**.

The encoder **104** may encode the data for transmission to the destination **110** via a communication channel **106**. The encoder **104** may compress the data to reduce a number of

bits or other symbols that are needed to transmit the data or information over the channel **106**. The encoder **104** may, for example, compress the characters by encoding the characters using codewords according to a lossless compression algorithm, such as Huffman encoding, which generates a unique sequence of bits for each possible character in the data stream. The encoder **104** may also compress the data by referencing previous sequences of characters and/or words which were encoded.

Rather than repeat each character in the previously encoded word, the encoder **104** may include a reference to the previously encoded word, such as a distance from the present position in the data stream, and the length of the previously encoded word. Encoder **104** may, for example, include the distance or number of characters back from the present position and/or current character that the previously encoded word was encoded and/or began, and the length of the referenced and/or previously encoded word, or number of characters in the referenced and/or previously encoded word. The encoder **104** may maintain a window of previously encoded characters and/or words. The encoder **104** may encode sequences of characters by reference to previously encoded sequences of characters within the window of previously encoded characters and/or words.

The encoder **104** may also encode sequences of characters by a reference to a word within a dictionary or corpus of words, and/or a reference to a transformation of the word. In an example implementation, the encoder **104** may distinguish between repeating a previously encoded sequence of characters and referencing a word in the dictionary or corpus of words by the distance value. A distance value that is within a size of the window of previously encoded characters and/or words may indicate that the encoder **104** has encoded the word by repeating a previously encoded sequence of characters. A distance value that exceeds the window size may indicate that the encoder **104** had encoded the sequence of characters by reference to the corpus of words or dictionary and/or the transformation. The sequence of characters may be encoded and/or compressed. In encoded and/or compressed form, the sequence of characters may be represented by a first number and/or second number. The first number and/or second number may represent the length value and/or the distance value.

The encoder **104** may send the encoded data to a decoder **108** via the communication channel **106**. While not shown in FIG. **1**, the system **100** may also include a transmitter, which may include a modulator for modulating and/or generating the signals for transmission of the data from the encoder **104** over the channel **106**, and a receiver, which may include a demodulator for demodulating and/or interpreting the signals received via the channel **106** and providing the encoded data to the decoder **108**.

The system **100** may also include the decoder **108**. The decoder **108** may decode the data according to an algorithm stored, understood, and/or agreed to by both the encoder **104** and the decoder **108**, and/or according to an algorithm designed to decode data encoded according to the algorithm implemented by the encoder **104**. The decoder **108** may, for example, decode codewords that represent individual characters, decode sequences of characters based on references to previously decoded characters, and/or may decode sequences of characters based on references to words in the corpus of words and/or references to transformations. The decoder **108** may have maintained a same codebook or encoding table to decode the codewords as the encoder **104** before receiving the encoded data, or may generate the codebook or encoding table based on information received from the encoder **104**, such as a map of characters to codewords or a frequency table used to generate the codebook or encoding table. The decoder **108** may have also maintained a same or matching corpus of words and/or index(es) of transformation as the encoder **104** before receiving the encoded data, or may generate the corpus of words and/or index(es) of transformation based on information received from the encoder **104**.

The decoder **108** may decode some characters as literals and/or codewords representing single characters, and decode some characters as members of previously decoded sequences, members of words, and/or members of transformed words. The encoded data may include an indicator, such as a specific sequence of bits or other symbols, indicating that subsequent bits or other symbols will refer to a previously encoded sequence of characters, a word, and/or a transformed word. The decoder **108** may, for example, divide a received number, which may represent a distance value, by a number of words in a corpus of words and/or subcorpus included in the corpus of words, to determine a quotient and a reminder. The decoder may retrieve a word from the corpus and/or subcorpus based on the remainder, and may perform a transformation on the retrieved word based on the quotient. The decoder **108** may decode the received number, and/or a second received number which may be included in a length/distance pair, as the transformed word.

The decoder **108** may, for example, determine whether a received distance value exceeds a window size of a window of previously decoded characters. If the distance value does not exceed the window size, then the decoder **108** may repeat a string and/or sequence of previously decoded characters from the window of previously decoded characters with a length based on a received length value at a position in the window of previously decoded characters based on the distance value. If the distance value does exceed the window size, then the decoder **108** may retrieve a word from a corpus of words. The decoder **108** may use the distance value as an index to select a word from the corpus of words.

If a group, series, or sequence of bits or other symbols refers to a previously encoded/decoded word, the group, series, or sequence of bits or other symbols may include a length value and a distance value. The length value and distance value may be included in a length/distance pair.

The decoder **108** may check, for example, whether the distance value included in the encoded data exceeds a window size. If the distance value does not exceed the window size, then the decoder **108** may use the distance value and the length value to repeat a previously decoded string of characters. If the distance value does exceed the window size, then the decoder **108** may use the length value to select a subcorpus within the corpus of words, and/or to select a transformation index. The decoder **108** may, for example, use the distance value to select a word, and/or a transformation, from the corpus or subcorpus of words and/or the selected transformation index. In an example implementation, the decoder **108** may divide the distance value by the number of words in the corpus or subcorpus. The decoder **108** may use the quotient to select a transformation from the index of transformations, and may use the remainder to select a word from the corpus or subcorpus of words. The decoder **108** may perform the selected transformation on the selected word. The decoder **108** may provide the decompressed and/or decoded version of the characters and/or data, which may include representations of characters including individual characters, repeated sequences of characters, and/or transformed words, to the destination **110**, which may be a computing device such as a memory device and/or file included in a computing system that may also include the decoder **108**.

FIG. **2** is a diagram of a computing system **200** according to an example implementation. The computing system **200** may include features of the encoder **104** and/or decoder **108**. The computing system **200** may be designed, for example, to only compress data, to only decompress data, or to both compress and decompress data according to a same and/or reciprocal compression/decompression algorithm. The functions, modules, and/or devices described with respect to the computing system **200** may be performed by and/or included in a single computing device, or may be divided and/or distributed between multiple computing devices. The computing system **200** may include an encoder **202** which performs any combination of the functions of the encoder **104**, a decoder **204**, which performs any combination of the functions of the decoder **108**, at least one memory device **206**, which may store instructions and/or data accessible by the encoder **202** and/or decoder **204**, a processor **208**, and/or an input/output module **210**.

The encoder **202** may encode and/or compress data according to any combination of the functions and techniques described herein. The encoder **202** may include a sequence scanner **212**. The sequence scanner **212** may scan sequences of characters and pass the sequences of characters to a match determiner **220**.

The sequence scanner **212** may include a window scanner **214**. The window scanner **214** may scan a window of previously encoded characters. The window **254**, an example of which is shown in FIG. **3**A, may be stored in the at least one memory device **206**. The window scanner **214** may, for example, scan the window of previously encoded characters at different positions and with different lengths. The window scanner **214** may, for example, scan the window from a first position for words of increasing length from a minimum length to a maximum length, such as from length two, length three, length four, length five, up to the maximum word length. The window scanner **214** may then scan the window from a second position for words from the minimum length to the maximum length. The window scanner **214** may scan the window from all possible starting or beginning positions in the window and for all allowable lengths, and pass the words resulting from the scans to the match determiner **220**

FIG. **3**A is a diagram showing recent data **300** and an example window **254**. As shown in FIG. **3**A, the recent data **300**, which may represent characters that have recently been encoded, in the order that they were encoded, may include characters numbered from zero to N−1. The characters may be represented by numbers that increase as time increases from the present to the past, as shown by the ‘t’ and arrow, with zero representing the most recently encoded character.

The window **254** of characters may represent a window size of characters that may be repeated by reference to distance and length. The window **254** may have a size, N. The size of the recent data, M, may represent the number of all characters recently encoded (such as the number of characters within a file that have been encoded), or may represent a number of encoded characters stored in the at least one memory device **206**.

The window scanner **214** may scan the window **254** for all possible sequences of characters for all possible starting positions in the window **254** from the minimum word size to the maximum word size, such as from N−1 to N−2, from N−1 to N−3, from N−1 to N−4, up to the maximum word size (the word size would be reflected by the difference between the beginning and end points of the scanned sequence plus one, e.g. ([beginning character] (N−1)−[ending character] (N−2)+1) would have a length of two), from N−2 to N−3, and so forth. The window scanner **214** may pass all of the scanned sequences within the window **254** to the match determiner **220** as candidate previous words and/or candidate previous sequences of characters (and/or previously encoded words, previously encoded strings of characters, or previously encoded sequences of characters) for repeating by reference to length and distance, along with a length value and a distance value for each scanned sequence. The match determiner **220** may determine whether a sequence of characters to be encoded matches a previously encoded sequence of characters in the window **254**. If the sequence of characters to be encoded does match a sequence of characters in the window **254**, then a previous sequence encoder **224** may encode the sequence of characters by a reference to a length and distance, with the distance referring to the beginning point (e.g. N−1) and the length indicating the number of characters and being used to determine the end point (e.g., end point=beginning point−length+1).

The window scanner **214** may also scan the window **254** to retrieve candidate current words and/or candidate current sequences of characters, which may be encoded by a reference to a candidate previous word and/or candidate previous sequence of characters or by a reference to a word in the corpus or subcorpus and/or a transformation in the transformation index. The window scanner **214** may scan the window **254** for all allowed lengths, such as from two or another minimum length sequentially to the longest allowed length, with the ending character being 0 for each possible present and/or most recent word and/or sequence of characters. For example, the window scanner **214** may scan characters 1 through 0 as a possible two-character candidate current word and/or candidate current sequence of characters, may scan characters 2 through 0 as a possible candidate current three-character word and/or candidate current sequence of characters, may scan characters 3 through 0 as a possible four-character candidate current word and/or candidate current sequence of characters, and so on until reaching either the beginning of the recent data (character M−1) or the beginning of the window **254** (character N−1) or the maximum allowed length of the word. The window scanner **214** may pass the scanned words and/or sequences of characters to the match determiner **220** as candidate current words and/or candidate current sequences of characters for encoding by reference to either candidate previous words and/or candidate previous sequences of characters or by reference to words in the corpus or subcorpus and/or transformation index. The window scanner **214** may also pass the beginning points in association with the candidate current words and/or candidate current sequences to the match determiner **220**.

FIG. **3**B is a diagram showing encoded data according to an example implementation. In this example, recent data **300** may include data encoded according to an alphabet including at least one codeword **302**. The codeword **302** may represent a literal encoding of a single character, and may include a sequence of bits or other symbols which represents a single character according to any encoding system, such as the American Standard Code for Information Interchange (ASCII), Unicode, or a lossless compression algorithm such as Huffman encoding. The codeword **302** may represent a character encoded by mapping characters to codewords according to an alphabet such as the alphabet **260** described with respect to FIG. **6**, and which may be decoded by mapping codewords to characters according to the alphabet. The recent data may include more codewords following the codeword **302**, representing a sequence of codewords and representing a sequence of encoded characters, as shown by the ellipses between the codeword **302** and an indicator **304**.

The recent data **300** may include one or more length/value pairs that either refer to previously encoded sequences of characters, or refer to a word in the corpus and/or a transformation. The recent data **300** may include an indicator **304** preceding the length/distance pair. The indicator **304** may be a unique sequence of bits that indicates that characters will be encoded by a succeeding length/distance pair which may include a length value and distance value. The unique sequence of bits representing the indicator **304** may be determined by the encoding system and/or codebook. The length/distance pair succeeding the indicator **304** may include a length **306**, which either indicates a length of the sequence of characters to be repeated or a subcorpus of words and index of transformations, and a distance **308**, which indicates either a distance from the present position that the sequence of characters begins or is used to determine the word and transformation.

The recent data **300** may include more blocks and/or codewords as represented by the ellipses after the distance **308**, which may include codewords representing individual characters, and/or length/value pairs which may include sequences of indicators, lengths, and/or distances. While the example of FIG. **3**B shows the length **306** preceding the distance **308**, the length and distance may be encoded in any order. In an example implementation, the indicator **304** need not be encoded separately, and the length and distance may instead be encoded with unique codewords and/or sequences of bits that are distinct from the codewords used to encode single characters.

Returning to FIG. **2**, the sequence scanner **212** may include a corpus scanner **216**. The corpus scanner **216** may scan a corpus of words as candidate stored words or corpus words to encode the candidate current words and/or candidate current sequences of characters by reference to the candidate stored words or corpus words. The corpus **256** may be stored in the at least one memory device **206**.

FIG. **4** shows the corpus **256** according to an example implementation. The corpus **256** may include multiple words which may be encoded by references to the words by the length/distance pair. In an example implementation, the corpus **256** may include subcorpuses **402**, **404**. The subcorpuses **402**, **404** may each include multiple words organized into an index and/or array. The words within the subcorpuses **402**, **404** and/or corpus **256** may be arranged in any order, such as alphabetically or based on their respective frequencies of occurrence as determined by sampling multiple data samples. The words in the subcorpuses **402**, **404** may be indexed from 0 to N−1 or M−1, for example, where N and M are the numbers of words in the respective subcorpuses **402**, **404**. The number of words, N, M, may be different for different subcorpuses **402**, **404**, or each subcorpus **402**, **404** may have a same number of words, according to example implementations.

The subcorpuses **402**, **404** may include words from different languages, such as English, Chinese, German, Arabic, or even words found in technical literature, such as computer science. The corpus **256** may include one subcorpus **402**, **404** for each language, or may include multiple subcorpuses for one or more languages to reduce the number of words in some subcorpuses **402**, **404** and/or to maintain a similar number of words in each subcorpus **402**, **404**.

Returning to FIG. **2**, the corpus scanner **216** may provide all of the words in the corpus **256** to the transformer **218**, or only some of the words which are candidates for including the most recent character (denoted 0 in FIG. **3**A). The corpus scanner **216** may, for example, perform a function such as a hash function on the most recent character (denoted by '0' in FIG. **3**A) to determine one or more languages and/or subcorpuses **402**, **404** (and associated transformation indexes described below) that may include the most recent character, thereby reducing the number of transformations to be performed by the transformer **218** and/or comparisons to be performed by the match determiner **220**.

The sequence scanner **212** may include a transformer **218**. The transformer **218** may perform transformations on the words received from the corpus scanner **216**. The transformer **218** may perform all transformations included in a transformation index on each of the words received from the sequence scanner, or may perform only transformations that may result in words ending with the most recent character. Transformations may include no change to the word, the addition of a space at the end of the word, the addition of a comma at the end of the word, capitalization of a first letter of the word, the addition of an 's' at the end of the word, an addition of a suffix to the end of the word, a change of font (such as italicization), a transformation such as a transformation listed in the appendix to this document, or any other change. The transformations available may be the same for all of the subcorpuses **402**, **404**, or may be different for each subcorpus **402**, **404**. The transformations may be different for each subcorpus **402**, **404** because different changes to words are made for each language, for example.

FIG. **5** shows an example of stored transformations **258**. The transformations **258** may be stored in the at least one memory device **206**. The stored transformations **258** may include multiple indices **502**, **504** which each include transformations. The indices may each include different numbers (e.g., N, M) of transformations, or may each include a same number of transformations. The values of N and M may be different in the examples described with reference to FIGS. **3**A, **4**, and **5**. The values in the index **502**, **504** may be used to retrieve a transformation.

The transformer **218** may perform transformations based on all the transformation indexes **502**, **504**, or only transformation indexes that may include transformations that will result in a word which has a last character matching the most recent character. The transformer **218** may select, for each word to be transformed, a transformation index **502**, **504** matching and/or associated with the subcorpus **402**, **404** from which the word was retrieved, and/or a transformation index based on the most recent character, such as by performing a function such as a hash function on the most recent character to select the transformation index **502**, **504**. Performing transformations on the words received from the corpus scanner **216** may result in transformed words. The transformer **218** may provide the transformed words as candidate transformed words to the match determiner **220**. The transformer **218** may also provide and/or pass a number or other identifier of the subcorpus **402**, **404**, a number or other identifier of the transformation index **502**, **504** (which may or may not be the same as the number or other identifier of the subcorpus **402**, **404**), an identifier of the word, and/or an identifier of the transformation, to the match determiner **220** in association with the transformed word.

The encoder **202** may include a match determiner **220**. The match determiner **220** may determine whether a candidate current word or candidate current sequence of characters received from the window scanner **214** matches either a

candidate previous word and/or candidate previous sequence of characters received from the window scanner **214** or a candidate transformed word received from the transformer **218**. The match determiner **220** may determine whether a match exists by comparing each candidate current word or candidate current sequence of characters received from the window scanner to each candidate previous word and/or candidate previous sequence of characters received from the window scanner **214** and each candidate transformed word received from the transformer **218**. If the match determiner **220** determines that more than one match exists, then the encoder **202** may encode the longest match and/or match with the most characters, or may select a match based on a cost metric. The cost metric may apply an information entropy model to choose a likely best match. The match determiner **220** may, for example, take into account the distance of the match and/or estimated entropy of the literals and/or characters that are replaced by the match. Some characters that were previously encoded as single characters may be re-encoded as previously encoded words and/or transformed words. If the match determiner **220** determines that a match does not exist, then the encoder may encode the most recent character as a single character.

The encoder **202** may include a character encoder **222**. If the match determiner **220** determined that there was no match, then the character encoder **222** may encode the most recent character as a literal, and/or with a single codeword, based on an encoding scheme as described above.

The encoder **202** may also include a previous sequence encoder **224**. The previous sequence encoder **224** may encode the sequence of characters if the match determiner **220** determined that the longest matching sequence of characters matched a previously encoded sequence of characters in the window **254**. The previous sequence encoder **224** may encode the sequence of characters by the length value and distance value. The previous sequence encoder **224** may include the length value, such as the length **306** shown in FIG. **3**B, and the distance value, such as the distance **308** shown in FIG. **3**B, of the longest match. The length value and distance value may have been received by the match determiner **220** in association with the candidate current word and/or candidate current sequence of characters.

If the match determiner **220** determined that the longest match was a transformed word, then the encoder **202** may encode the current or most recent sequence of characters a reference to the word in the corpus **256** and/or subcorpus **402**, **404**, and/or a transformation in the transformations **258** and/or one of the transformation indexes **502**, **504**. The word may be encoded, for example, by the length/distance pair. The length may indicate which subcorpus **402**, **404** the word should be found in and/or from which transformation index **502**, **504** should be selected. The word within the subcorpus **402**, **404** may be indexed using the distance value. In an example implementation, when decoded, the word within the subcorpus **402**, **404** may be indexed by the remainder resulting from dividing the distance value by the number of words in the subcorpus **402**, **404**, and/or the transformation may be indexed by the quotient resulting from dividing the distance value by the number of words in the subcorpus **402**, **404**.

The encoder **202** may include a corpus/transformation encoder **226**. The corpus/transformation encoder **226** may encode sequences of words when the match determiner **220** has determined that the longest match is a transformed word, and/or the current or most recent sequence of characters matches a word included in the corpus **256**, and/or subcorpus **402**, **404**, or is one transformation away from a word included in the corpus **256** and or subcorpus **402**, **404**.

The corpus/transformation encoder **226** may include a multiplier **228** and an adder **230**. The multiplier **228** may multiply the number of words in the subcorpus **402**, **404** from which the word is retrieved by an index number of the transformation performed on the word to achieve the match; the index number of the transformation may have been provided by the transformer **218** in association with the candidate transformed word which had the longest match. The adder **230** may add an index number of the word to the product determined by the multiplier **228**; the index number may have been provided by the corpus scanner **216** and/or transformer in association with the candidate transformed word which had the longest match. The sum of the value determined by the adder **230** and the multiplier **228** may be used to provide the distance value in the length/distance pair, such as a distance **308**. The length value in the length/distance pair may indicate the subcorpus **402**, **404** and/or transformation index **502**, **504** which stores the word and/or transformation of the transformed word with the longest match.

The computer system **200** may include a decoder **204**. The decoder **204** may decode and/or decompress data received by the computing system **200** according to any combination of the functions and techniques described herein. The decoder **204** may decode and/or decompress data received by the computing system **200** that was decoded and/or decompressed according to an algorithm similar to that described herein with respect to the encoder **202**. The decoder **204** may receive codewords representing individual characters in accordance with the alphabet **260** described with respect to FIG. **6**. The decoder **204** may also receive a first value and/or a second value, which may be included in a length/distance pair in which the first value represents a length value and/or the second value represents a distance value, respectively, or the first value may represent a distance value and/or the second value may represent a length value.

The decoder **204** may include a match checker **232**. The match checker **232** may determine whether data has been encoded based on a match to either previous data within the window **254** or a word in the corpus **256** and/or a transformation, or was encoded as a literal and/or by representing a single character with a codeword. The match checker **232** may determine whether the data was encoded based on a match by checking for an indicator **304**, or based on codewords or other representations of a length and/or distance value that indicate encoding based on a match.

If the match checker **232** determines that there is no match to either a previously encoded data or to words and/or transformations, the decoder **204** may decode the data as literals and/or decode a single, most recent codeword or other representation as a single character. If the match checker **232** determines that the data has been encoded by a reference to previously encoded window of data, then the decoder **204** may decode the data by repeating a previously decoded string of characters. If the match checker **232** determines that the data has been encoded by a reference to a word in the corpus **256** and/or a transformation, then the data may be decoded by retrieving the word and/or transformation, and if a transformation is retrieved, performing the retrieved transformation on the retrieved word.

The decoder **204** may include a codeword decoder **234**. The codeword decoder **234** may decode the data and/or most recent codeword or other representation as a literal, and/or as a single character. The codeword decoder **234** may decode the data according to an encoding/decoding scheme, such as ASCII, Unicode, or a compression algorithm, such as Huffman encoding, which was mutually understood and/or agreed upon by the decoder **108** (which may include the decoder **204**) and encoder **104** (which may include an encoder similar to the encoder **202**).

The decoder **204** may include a distance comparator **236**. The distance comparator **236** may compare the distance value to the window size. If the distance value is less than or equal to the window size, then the decoder **204** may decode the data by repeating a previously decoded sequence of characters. If the distance exceeds the window size, then the decoder **204** may decode the data retrieving the words from the corpus **256**, and/or subcorpus **402**, **404**, and/or performing a transformation stored in the stored transformations **258** and/or one of the transformations indexes **502**, **504** on the retrieved word.

The decoder **204** may include a string repeater **238**. The string repeater **238** may repeat a previously decoded string or sequence of characters if the distance comparator **236** determined that the length was less than or equal to the window size. The string repeater **238** may repeat the previously decoded string of characters beginning at a point indicated by the distance value and ending at a point determined based on both the distance value and the length value.

The decoder **204** may include a divider **240**. If the match checker **232** determined that there was a match, and a distance comparator **236** determined that the received distance exceeded the window size **254**, the divider **240** may perform division to determine a word index number and/or a transformation index number. The divider **240** may determine the transformation index number based on a quotient by dividing a received distance value by a number of words in the corpus **256** and/or subcorpus **402**, **404** from which the word is included. The divider **240** may determine the word index number based on a remainder by dividing a received distance value by a number of words in the corpus **256** and/or subcorpus **402**, **404** from which the word is included. The subcorpus **402**, **404** may be determined based on the length value.

The decoder **204** may include a word retriever **244**. The word retriever **244** may retrieve a word if the match checker **232** determined a match and the distance comparator **236** determined that the received distance value exceeded the window size. The word retriever **244** may retrieve a word from the corpus **256**. The word retriever **244** may include a corpus selector **246**. The corpus selector **246** may select a subcorpus **402**, **404** from the corpus **256** based on the received length value. The subcorpuses **402**, **404** may, for example, each be associated with an integer value, such as 0, 1, 2, 3, 4, etc. The corpus selector **246** may select the subcorpus **402**, **404** associated with the value included in the received length value. After the corpus selector **246** has selected the subcorpus **402**, **404**, the word retriever **244** may retrieve the word from the subcorpus **402**, **404**. The word retriever **244** may retrieve the word from the subcorpus **402**, **404** based on the remainder **243** determined by the divider **240**. The word retriever **244** may, for example, use the remainder **243** as an index value to select the word from the subcorpus **402**, **404**.

The decoder **204** may include a transformer **248**. The transformer **248** may select a transformation based on the quotient **242** determined by the divider **240**. The transformer **248** may use the quotient **242** as an index to select the transformation from the stored transformations **258** and/or selected index of transformation **502**, **504**. In an example in which the transformations **258** include different sets, arrays, and/or indexes of transformations for each length value and/or each subcorpus **402**, **404**, the transformer **248** may include an index selector **250**. The index selector **250** may select a transformation index **502**, **504** from which the transformation matrix will be selected. The index selector **250** may select a transformation index **502**, **504** based on the received length value and/or based on the subcorpus **402**, **404**. In an example implementation, the transformation index **502**, **504** may each be associated with one subcorpus **402**, **404**.

The transformer **248** may select a transformation from the stored transformations **258** and/or selected transformation index **502**, **504**. The transformer **248** may use the quotient **242** as an index into the selected transformation index **502**, **504** to select a transformation. The transformer **248** may perform the selected transformation on the retrieved word. After the transformer **248** has performed the transformation on the retrieved word, the decoder **204** may add the transformed word to an output stream of decoded characters.

The at least one memory device **206** may include a non-transitory computer-readable storage medium. The memory device **206** may include a single memory device, or may include multiple memory devices. The memory device (s) **206** may include instructions **252** stored thereon. Instructions **252** may include instructions that may be executed by the processor **208** to cause the computing system **200** to perform any combination of the methods and/or functions described herein.

The memory **206** may store the window **254**. The window **254** may include previously encoded characters or previously decoded characters, which may be referenced by the string repeater **238** and/or referenced by the previous sequence encoder **224**. The size and/or length of the window **254** may be based on available memory or cache, or may be shortened to be less than a window length that would be possible using available memory or cache to facilitate more instances of encoding characters as transformed words.

The memory **206** may store the corpus **256**. The corpus **256** may include words that may be retrieved by the corpus scanner **216** and/or word retriever **244**. The corpus **256** may be subdivided into subcorpuses **402**, **404**.

The memory device **206** may store the transformations **258**. The transformations **258** may include transformations that may be retrieved and performed by the transformer **218** and/or transformer **248**. The transformations **258** may include a number of transformation indexes **502**, **504** based on, and/or equal to, the number of subcorpuses **402**, **404**.

The memory **206** may also include an alphabet **260**. The alphabet **260** may include encodings for characters that may be received in encoded form. The alphabet **260** may include, for example, a fixed-length encoding scheme, such as ASCII or Unicode, or may include encodings according to compression methods such as Huffman encoding. The alphabet **260** may have been stored by the computer system **200** before receiving data, or may have been generated based on information associated with the encoded data either before or after the encoding. The alphabet **260** may, for example, have been previously stored by both the encoder **202** and decoder **204** before any encoding or decoding, or may be generated based on the data to be decoded.

If the alphabet **260** was generated based on the data to be encoded, the encoder **104** may send the alphabet **260** to the decoder **108** in association with the encoded data. The alphabet **260** may have been literally included with the data received, such as by including the characters and associated representations in a header file, or the decoder **108** may generate the alphabet **260** based on information received from the encoder **104** in association with the encoded data, such as a frequency distribution that may be used to construct a Huffman encoding table.

FIG. **6** shows an example of a stored alphabet **260** mapping characters to encodings. As shown in FIG. **6**, characters **602** may map to encodings **604** in a one-to-one correspondence. The characters **602** may include alphanumeric characters and punctuation marks, which may also be used to represent the length value and the distance value, or the encodings **604** may include distinct representations of length and/or distance values that represent length and/or distance values but do not represent numeric values that are not encoded by reference to previously encoded/decoded words or words and/or transformations stored in the corpus **256** and/or stored transformations **258**. In the example in which distinct encodings **604** are used to represent length and distance values, the length and distance values may be represented by a shared set of values mapped to encodings, or the encodings used to represent length values may be distinct from the encodings used to represent distance values.

The computing system **200** may include a processor **208**. The processor **208** may include a processor capable of executing instructions, such as the instructions **252** stored in the memory **206**, to perform functions, processes, and/or methods such as the functions, processes, and/or methods described herein.

The computing system **200** may also include an input/output module **210**. The input/output module **210** may receive input and/or provide output. The input/output module **210** may include a single device that performs both input and output functions, or may include two or more modules that each perform either input functions or output functions. The input/output module **210** may, for example, receive the encoded data, output the decoded data, receive instructions from a user, and/or provide the decoded data to a display for viewing by the user.

FIG. **7** is a flowchart showing a method **700** for encoding data according to an example implementation. The method **700** may include the window scanner **214** scanning a sequence of characters for candidate current words and/or candidate current sequences of characters (**702**), as described above with respect to FIG. **2**. The sequence of characters may include characters in the window **254** of characters.

The method **700** may include the match determiner **220** determining whether any of the candidate current words and/or candidate current sequences of characters match a previously encoded sequence (**704**). The match determiner **220** may determine whether any of the candidate current sequences ending with the most recent character matches any of the previously encoded sequences. If the scanned sequence of characters does match a previously encoded sequence, and/or if the match determiner **220** determines that the match between the scanned sequence of characters is longer than any other match (either with previously encoded characters or a word in the corpus **256**), then the method **700** may include the previous sequence encoder **224** encoding the sequence with a reference to a previously encoded sequence (**706**). The sequence may be encoded with reference to a previously encoded sequence by including a length value indicating a length of the previously encoded sequence, and a distance value indicating a distance from the present position and/or most recent character.

If the scanned sequence of characters does not match a previously encoded sequence, then the method **700** may include the match determiner **220** determining whether the scanned sequence of characters matches a word in the corpus **256** (**708**). In an example, the match determiner **220** may determine whether the scanned sequence of characters matches a word in the corpus **256** even if the scanned sequence of characters does match a previously encoded sequence. If the scanned sequence of characters does match a word in the corpus **256**, and/or if the match determiner **220** determines that the longest match of the scanned sequence of characters is a match to a word in the corpus **256**, then the method **700** may include encoding the sequence of characters with a reference to the word in the corpus (**710**).

The scanned sequence of characters may be encoded with a reference to the word in the corpus by, for example, the length value indicating the subcorpus **402**, **404** and the distance value indexing the word in the corpus **256**.

If the scanned sequence of characters does not match a word in the corpus **256**, then the method **700** may include determining whether the scanned sequence of characters is one transformation away from a word in the corpus **256** (**712**). In an example, the match determiner **220** may determine whether the scanned sequence of characters is one transformation away from a word in the corpus **256** even if the match determiner **220** determined that the scanned sequence of characters matches a previously encoded sequence and/or that the scanned sequence of characters matches a word in the corpus **256**.

If the scanned sequence of characters is one transformation away from a word in the corpus **256**, and/or if the match determiner **220** determines that the longest match of the scanned sequence of words is to a transformed word, then the method **700** may include the corpus/transformation encoder **226** encoding the scanned sequence of characters with a reference to the word and the transformation (**716**). The scanned sequence of characters may be encoded with a reference to the word in the corpus **256** by the length value indicating the subcorpus **402**, **404** and the transformation index, and the distance value being used to determine both the word and the transformation. If the scanned sequence of characters is not one transformation away from a word in the corpus, then the method **700** may include encoding the scanned sequence of characters as single characters with individual codewords (**714**). Encoding the scanned sequence of characters as single characters may include encoding each individual character using a codeword or other encoding representation based on the alphabet **260**.

FIG. **8** is a flowchart showing a method **800** for decoding data according to an example implementation. The method **800** may include the decoder **204** receiving a sequence of encoded characters (**802**). The encoded characters may be received as part of a file. The method **800** may include the match checker **232** determining whether the encoded character(s) are encoded as a match to previously encoded characters or a match to a stored word and/or transformation (**804**). If the encoded character(s) is not encoded as a match, then the method **800** may include the decoder **204** decoding the encoded character as a single character (**806**). The encoded character may be decoded as a literal, translating a codeword into a single character, based on the alphabet **260** stored in the memory **206**.

If the encoded character(s) is a match, then the distance comparator **236** may determine whether the encoded characters match a previously decoded word (**808**). The decoder **204** may determine whether the encoded data unit matches a previously decoded word by the distance comparator **236** comparing a received distance value to the window size. If the distance value is less than or equal to the window size, then the distance comparator **236**, and/or decoder **204**, may determine that the encoded data unit does match a previously decoded word, and repeat the previously decoded word (**810**). The string repeater **238** of the decoder **204** may repeat the previously decoded word by repeating the sequence of characters that are the distance value previous from a present or current character, for the number of characters equal to a received length value.

If the distance comparator **236** of the decoder **204** determines that the encoded characters do not match a previously decoded word, then the decoder **204** may determine a corpus and/or a transformation (**812**). The decoder **204** may determine the corpus and/or a transformation by the corpus selector **246** selecting the corpus **256** and/or subcorpus **402**, **404** based on the length value, and/or the index selector **250** may select the transform index **502**, **504** based on the length value.

After the word retriever determines the corpus and the transformer **248** determines the transformation, the divider **240** may determine the quotient and remainder of the distance value (**814**). The divider **240** of the decoder **204** may determine the quotient **242** by dividing the distance value by the number of words in the corpus **256** or subcorpus **402**, **404**. The divider **240** of the decoder **204** may determine the remainder **243** by performing a modulo operation, dividing the distance value by the number of words in the corpus **256** or subcorpus **402**, **404**, and determining the remainder **243**.

The word retriever **244** of the decoder **204** may then retrieve the word (**816**). The word retriever **244** may retrieve the word by using the remainder **243** as an index into the corpus **256** or subcorpus **402**, **404**.

The decoder **204** may then select a transformation (**818**). The transformer **248** of the decoder **204** may select a transformation by using the quotient **242** as an index into the transformation index **502**, **504** and/or transformations **258**.

After retrieving the word (**816**) and selecting the transformation (**818**), the transformer **248** of the decoder **204** may perform the selected transformation on the retrieved word (**820**). The decoder **204** may perform the selected transformation on the retrieved word by, for example, adding a space after the word, capitalizing a first letter of the word, adding a character, such as 's' to the end of the word, adding a suffix to the end of the word, omitting an indexed character or number of characters from the word (e.g., "Omit1" may indicate omitting the character indexed by 1 or omitting the first character from the word, "Omit5" may indicate omitting the character indexed by 5 from the word or omitting the first five characters from the word), or changing a font of the word.

FIG. **9** is a flowchart showing a method **900** for decompressing data according to an example implementation. The method **900** may include receiving, via an electronic transmission medium, a compressed sequence of characters, the compressed sequence of characters being represented by at least a first received number (**902**). The method **900** may also include dividing the first received number by a number of words in a corpus of words to determine a quotient and a remainder (**904**). The method **900** may also include retrieving a word from the corpus of words based on the remainder, the corpus of words being stored on at least one memory device (**906**). The method **900** may also include retrieving a transformation from a transformation index based on the quotient, the transformation index being stored on the at least one memory device (**908**). The method **900** may also include performing the retrieved transformation on the retrieved word (**910**). The method **900** may also include sending representations of characters included the transformed word to a computing device, the representations of characters included in the transformed word being a decompressed version of the received compressed sequence of characters (**912**).

According to an example embodiment, retrieving the word from the corpus of words may include indexing the corpus of words as an array using the remainder.

According to an example embodiment, the instructions may be further configured to cause the computing system to receive the number via a communication channel.

According to an example embodiment, the instructions may be further configured to cause the computing system to output the transformed word.

According to an example embodiment, the instructions may be further configured to cause the computing system to output the transformed word within a sequence of characters, the sequence of characters including the transformed word and characters that were individually decoded by mapping codewords to characters.

According to an example embodiment, the instructions may be further configured to cause the computing system to output the transformed word within a sequence of characters, the sequence of characters including the transformed word and words that were generated by referencing words that had previously been decoded.

According to an example embodiment, the instructions may be further configured to cause the computing system to select the corpus of words from at least a first corpus of words including words from a first language and a second corpus of words including words from a second language.

According to an example embodiment, the received number may be a first received number, and the instructions may be further configured to cause the computing system to select a subcorpus from multiple subcorpuses included in the corpus of words based on a second received number.

According to an example embodiment, the received number may be a first received number, and the performing the transformation may include performing the transformation on the retrieved word based on the quotient and a second received number.

FIG. **10** is a flowchart showing a method **1000** for decompressing data according to an example implementation. The method **1000** may include receiving, via an electronic transmission medium, a compressed sequence of characters, the compressed sequence of characters being represented by at least a distance value and a length value (**1002**). The method **1000** may include determining whether the distance value exceeds a window size of a window of previously decoded characters, the window of previously decoded characters being stored on at least one memory device (**1004**). The method **1000** may include, if the distance value does not exceed the window size, repeating a sequence of previously decoded characters from the window of previously decoded characters with a length based on the length value at a position in the window of previously decoded characters based on the distance value (**1006**). The method **1000** may include, if the distance value does exceed the window size, retrieving a word from a corpus of words, the corpus of words being stored on the at least one memory device (**1008**). The method **1000** may include sending representations of characters included in the retrieved word to a computing device, the representations of characters included in the retrieved word being a decompressed version of the received compressed sequence of characters (**1010**).

According to an example embodiment, the distance value may be included in a length/distance pair and the length value is included in the length/distance pair.

According to an example embodiment, the retrieving the word from the corpus of words may include retrieving the word from the corpus of words based on the length value and the distance value.

According to an example embodiment, the retrieving the word from the corpus of words may include determining a subcorpus of the corpus of words based on the length value, determining a remainder by dividing the distance value by a number of words in the subcorpus, and indexing the retrieved word within the subcorpus based on the remainder.

According to an example embodiment, the method **1000** may further include performing a transformation on the retrieved word.

According to an example embodiment, the method **1000** may further include performing a transformation on the retrieved word based on the distance value.

According to an example embodiment, the method **1000** may further include performing a transformation on the retrieved word based on the distance value and a number of words in the corpus of words.

According to an example embodiment, the word may be retrieved from a subcorpus included in the corpus of words, the subcorpus being selected based on the length value.

According to an example embodiment, the method **1000** may further include performing a transformation on the retrieved word by selecting a subcorpus of the corpus of words based on the length value, determining a quotient of the distance divided by a number of words in the selected subcorpus, and selecting the transformation based on the quotient.

According to an example embodiment, the method **1000** may further include maintaining a first subcorpus for words in the corpus of words of a first language and a second subcorpus for words in the corpus of words of a second language.

According to an example embodiment, the retrieving the word within the corpus of may include indexing the corpus of words using a remainder based on dividing the distance value by a number of words in the corpus of words.

According to an example embodiment, the method **1000** may further include selecting a subcorpus from the corpus of words based on the length value, selecting an index of transformations from the at least one memory device based on the length value, and performing a transformation on the retrieved word, the transformation being selected from the selected index of transformations.

According to an example embodiment, the retrieved word may be selected based on a remainder determined by dividing the distance value by a number of words in the subcorpus; and the transformation may selected by indexing the selected index of transformations based on a quotient determined by dividing the distance value by the number of words in the subcorpus.

According to an example embodiment, the corpus of words may store the words in an order based on their frequencies.

FIG. **11** is a flowchart showing a method **1100** for compressing data according to an example implementation. The method **1100** may include determining whether a sequence of characters matches a word included in a corpus of words or matches a transformed version of the word, the corpus of words being stored in at least one memory device and the transformation performed on the word being stored in the at least one memory device (**1102**). If the sequence if characters does not match the word included in the corpus of words and is not one transformation away from the word, the method **1100** may include encoding the sequence of characters as a sequence of codewords (**1104**). If the sequence of characters matches the word included in the corpus of words, the method **1100** may include encoding the sequence of characters with a reference to the word (**1106**). If the sequence of characters matches the transformed version of the word, the method **1100** may include encoding the sequence of characters with a reference to the word and a reference to the transformation (**1108**).

According to an example embodiment, the method **1100** may further include determining whether the sequence of characters matches a previously encoded sequence of characters, and if the sequence of characters does match the previously encoded sequence of characters, encoding the sequence of characters with a reference to the previously encoded sequence of characters.

According to an example embodiment, the reference to the word and the reference to the transformation may include a number based on multiplying a number of words in a corpus by a number associated with the transformation and adding a number associated with the word.

FIG. **12** shows an example of a generic computer device **1200** and a generic mobile computer device **1250**, which may be used with the techniques described herein. Computing device **1200** is intended to represent various forms of digital computers, such as laptops, desktops, workstations, personal digital assistants, servers, blade servers, mainframes, and other appropriate computers. Computing device **1250** is intended to represent various forms of mobile devices, such as personal digital assistants, cellular telephones, smart phones, and other similar computing devices. The components shown here, their connections and relationships, and their functions, are meant to be exemplary only, and are not meant to limit implementations of the inventions described and/or claimed in this document.

Computing device **1200** includes a processor **1202**, memory **1204**, a storage device **1206**, a high-speed interface **1208** connecting to memory **1204** and high-speed expansion ports **1210**, and a low speed interface **1212** connecting to low speed bus **1214** and storage device **1206**. Each of the components **1202**, **1204**, **1206**, **1208**, **1210**, and **1212**, are interconnected using various busses, and may be mounted on a common motherboard or in other manners as appropriate. The processor **1202** can process instructions for execution within the computing device **1200**, including instructions stored in the memory **1204** or on the storage device **1206** to display graphical information for a GUI on an external input/output device, such as display **1216** coupled to high speed interface **1208**. In other implementations, multiple processors and/or multiple buses may be used, as appropriate, along with multiple memories and types of memory. Also, multiple computing devices **1200** may be connected, with each device providing portions of the necessary operations (e.g., as a server bank, a group of blade servers, or a multi-processor system).

The memory **1204** stores information within the computing device **1200**. In one implementation, the memory **1204** is a volatile memory unit or units. In another implementation, the memory **1204** is a non-volatile memory unit or units. The memory **1204** may also be another form of computer-readable medium, such as a magnetic or optical disk.

The storage device **1206** is capable of providing mass storage for the computing device **1200**. In one implementation, the storage device **1206** may be or contain a computer-readable medium, such as a floppy disk device, a hard disk device, an optical disk device, or a tape device, a flash memory or other similar solid state memory device, or an array of devices, including devices in a storage area network or other configurations. A computer program product can be tangibly embodied in an information carrier. The computer program product may also contain instructions that, when executed, perform one or more methods, such as those described above. The information carrier is a computer- or machine-readable medium, such as the memory **1204**, the storage device **1206**, or memory on processor **1202**.

The high speed controller **1208** manages bandwidth-intensive operations for the computing device **1200**, while the low speed controller **1212** manages lower bandwidth-intensive operations. Such allocation of functions is exemplary only. In one implementation, the high-speed controller **1208** is coupled to memory **1204**, display **1216** (e.g., through a graphics processor or accelerator), and to high-speed expansion ports **1210**, which may accept various expansion cards (not shown). In the implementation, low-speed controller **1212** is coupled to storage device **1206** and low-speed expansion port **1214**. The low-speed expansion port, which may include various communication ports (e.g., USB, Bluetooth, Ethernet, wireless Ethernet) may be coupled to one or more input/output devices, such as a keyboard, a pointing device, a scanner, or a networking device such as a switch or router, e.g., through a network adapter.

The computing device **1200** may be implemented in a number of different forms, as shown in the figure. For example, it may be implemented as a standard server **1220**, or multiple times in a group of such servers. It may also be implemented as part of a rack server system **1224**. In addition, it may be implemented in a personal computer such as a laptop computer **1222**. Alternatively, components from computing device **1200** may be combined with other components in a mobile device (not shown), such as device **1250**. Each of such devices may contain one or more of computing device **1200**, **1250**, and an entire system may be made up of multiple computing devices **1200**, **1250** communicating with each other.

Computing device **1250** includes a processor **1252**, memory **1264**, an input/output device such as a display **1254**, a communication interface **1266**, and a transceiver **1268**, among other components. The device **1250** may also be provided with a storage device, such as a microdrive or other device, to provide additional storage. Each of the components **1250**, **1252**, **1264**, **1254**, **1266**, and **1268**, are interconnected using various buses, and several of the components may be mounted on a common motherboard or in other manners as appropriate.

The processor **1252** can execute instructions within the computing device **1250**, including instructions stored in the memory **1264**. The processor may be implemented as a chipset of chips that include separate and multiple analog and digital processors. The processor may provide, for example, for coordination of the other components of the device **1250**, such as control of user interfaces, applications run by device **1250**, and wireless communication by device **1250**.

Processor **1252** may communicate with a user through control interface **1258** and display interface **1256** coupled to a display **1254**. The display **1254** may be, for example, a TFT LCD (Thin-Film-Transistor Liquid Crystal Display) or an OLED (Organic Light Emitting Diode) display, or other appropriate display technology. The display interface **1256** may comprise appropriate circuitry for driving the display

1254 to present graphical and other information to a user. The control interface **1258** may receive commands from a user and convert them for submission to the processor **1252**. In addition, an external interface **1262** may be provide in communication with processor **1252**, so as to enable near area communication of device **1250** with other devices. External interface **1262** may provide, for example, for wired communication in some implementations, or for wireless communication in other implementations, and multiple interfaces may also be used.

The memory **1264** stores information within the computing device **1250**. The memory **1264** can be implemented as one or more of a computer-readable medium or media, a volatile memory unit or units, or a non-volatile memory unit or units. Expansion memory **1274** may also be provided and connected to device **1250** through expansion interface **1272**, which may include, for example, a SIMM (Single In Line Memory Module) card interface. Such expansion memory **1274** may provide extra storage space for device **1250**, or may also store applications or other information for device **1250**. Specifically, expansion memory **1274** may include instructions to carry out or supplement the processes described above, and may include secure information also. Thus, for example, expansion memory **1274** may be provide as a security module for device **1250**, and may be programmed with instructions that permit secure use of device **1250**. In addition, secure applications may be provided via the SIMM cards, along with additional information, such as placing identifying information on the SIMM card in a non-hackable manner.

The memory may include, for example, flash memory and/or NVRAM memory, as discussed below. In one implementation, a computer program product is tangibly embodied in an information carrier. The computer program product contains instructions that, when executed, perform one or more methods, such as those described above. The information carrier is a computer- or machine-readable medium, such as the memory **1264**, expansion memory **1274**, or memory on processor **1252**, that may be received, for example, over transceiver **1268** or external interface **1262**.

Device **1250** may communicate wirelessly through communication interface **1266**, which may include digital signal processing circuitry where necessary. Communication interface **1266** may provide for communications under various modes or protocols, such as GSM voice calls, SMS, EMS, or MMS messaging, CDMA, TDMA, PDC, WCDMA, CDMA2000, or GPRS, among others. Such communication may occur, for example, through radio-frequency transceiver **1268**. In addition, short-range communication may occur, such as using a Bluetooth, WiFi, or other such transceiver (not shown). In addition, GPS (Global Positioning System) receiver module **1270** may provide additional navigation- and location-related wireless data to device **1250**, which may be used as appropriate by applications running on device **1250**.

Device **1250** may also communicate audibly using audio codec **1260**, which may receive spoken information from a user and convert it to usable digital information. Audio codec **1260** may likewise generate audible sound for a user, such as through a speaker, e.g., in a handset of device **1250**. Such sound may include sound from voice telephone calls, may include recorded sound (e.g., voice messages, music files, etc.) and may also include sound generated by applications operating on device **1250**.

The computing device **1250** may be implemented in a number of different forms, as shown in the figure. For example, it may be implemented as a cellular telephone **1280**. It may also be implemented as part of a smart phone **1282**, personal digital assistant, or other similar mobile device.

Implementations of the various techniques described herein may be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. Implementations may implemented as a computer program product, i.e., a computer program tangibly embodied in an information carrier, e.g., in a machine-readable storage device or in a propagated signal, for execution by, or to control the operation of, data processing apparatus, e.g., a programmable processor, a computer, or multiple computers. A computer program, such as the computer program(s) described above, can be written in any form of programming language, including compiled or interpreted languages, and can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network.

Method steps may be performed by one or more programmable processors executing a computer program to perform functions by operating on input data and generating output. Method steps also may be performed by, and an apparatus may be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit).

Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. Elements of a computer may include at least one processor for executing instructions and one or more memory devices for storing instructions and data. Generally, a computer also may include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto-optical disks, or optical disks. Information carriers suitable for embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks. The processor and the memory may be supplemented by, or incorporated in special purpose logic circuitry.

To provide for interaction with a user, implementations may be implemented on a computer having a display device, e.g., a cathode ray tube (CRT) or liquid crystal display (LCD) monitor, for displaying information to the user and a keyboard and a pointing device, e.g., a mouse or a trackball, by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input.

Implementations may be implemented in a computing system that includes a back-end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front-end component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation, or any combination of such back-end, middleware, or front-end components. Components may be interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network (LAN) and a wide area network (WAN), e.g., the Internet.

While certain features of the described implementations have been illustrated as described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the embodiments of the invention.

What is claimed is:

1. A non-transitory computer-readable storage medium comprising instructions stored thereon that, when executed by at least one processor, are configured to cause a computing system to decompress data by:

receiving, via an electronic transmission medium, a compressed sequence of characters, the compressed sequence of characters being represented by at least a first received number;

dividing the first received number by a number of words in a corpus of words to determine a quotient and a remainder;

retrieving a word from the corpus of words based on the remainder, the corpus of words being stored on at least one memory device;

retrieving a transformation from a transformation index based on the quotient, the transformation index being stored on the at least one memory device;

performing the retrieved transformation on the retrieved word; and

sending representations of characters including the transformed word to a computing device, the representations of characters included in the transformed word being a decompressed version of the received compressed sequence of characters.

2. The non-transitory computer-readable storage medium of claim **1**, wherein retrieving the word from the corpus of words includes indexing the corpus of words as an array using the remainder.

3. The non-transitory computer-readable storage medium of claim **1**, wherein the instructions are further configured to cause the computing system to receive the number via a communication channel.

4. The non-transitory computer-readable storage medium of claim **1**, wherein the instructions are further configured to cause the computing system to output the transformed word.

5. The non-transitory computer-readable storage medium of claim **1**, wherein the instructions are further configured to cause the computing system to output the transformed word within a sequence of characters, the sequence of characters including the transformed word and characters that were individually decoded by mapping codewords to characters.

6. The non-transitory computer-readable storage medium of claim **1**, wherein the instructions are further configured to cause the computing system to output the transformed word within a sequence of characters, the sequence of characters including the transformed word and words that were generated by referencing words that had previously been decoded.

7. The non-transitory computer-readable storage medium of claim **1**, wherein the instructions are further configured to cause the computing system to select the corpus of words from at least a first corpus of words including words from a first language and a second corpus of words including words from a second language.

8. The non-transitory computer-readable storage medium of claim **1**, wherein:

the received number is a first received number; and

the instructions are further configured to cause the computing system to select a subcorpus from multiple subcorpuses included in the corpus of words based on a second received number.

9. The non-transitory computer-readable storage medium of claim **1**, wherein:

the received number is a first received number; and

the performing the transformation includes performing the transformation on the retrieved word based on the quotient and a second received number.

10. A non-transitory computer-readable storage medium comprising instructions stored thereon that, when executed by at least one processor, are configured to cause a computing system to decompress data by:

receiving, via an electronic transmission medium, a compressed sequence of characters, the compressed sequence of characters being represented by at least a distance value and a length value;

determining whether the distance value exceeds a window size of a window of previously decoded characters, the window of previously decoded characters being stored on at least one memory device;

if the distance value does not exceed the window size, repeating a sequence of previously decoded characters from the window of previously decoded characters with a length based on the length value at a position in the window of previously decoded characters based on the distance value;

if the distance value does exceed the window size, retrieving a word from a corpus of words, the corpus of words being stored on the at least one memory device; and

sending representations of characters included in the retrieved word to a computing device, the representations of characters included in the retrieved word being a decompressed version of the received compressed sequence of characters.

11. The non-transitory computer-readable storage medium of claim **10**, wherein the distance value is included in a length/distance pair and the length value is included in the length/distance pair.

12. The non-transitory computer-readable storage medium of claim **10**, wherein the retrieving the word from the corpus of words includes retrieving the word from the corpus of words based on the length value and the distance value.

13. The non-transitory computer-readable storage medium of claim **10**, wherein the retrieving the word from the corpus of words includes:

determining a subcorpus of the corpus of words based on the length value;

determining a remainder by dividing the distance value by a number of words in the subcorpus; and

indexing the retrieved word within the subcorpus based on the remainder.

14. The non-transitory computer-readable storage medium of claim **10**, wherein the instructions are further configured to cause the computing system to perform a transformation on the retrieved word.

15. The non-transitory computer-readable storage medium of claim **10**, wherein the instructions are further configured to cause the computing system to perform a transformation on the retrieved word based on the distance value.

16. The non-transitory computer-readable storage medium of claim **10**, wherein the instructions are further configured to cause the computing system to perform a transformation on the retrieved word based on the distance value and a number of words in the corpus of words.

17. The non-transitory computer-readable storage medium of claim **16**, wherein the word is retrieved from a subcorpus included in the corpus of words, the subcorpus being selected based on the length value.

18. The non-transitory computer-readable storage medium of claim **10**, wherein the instructions are further configured to cause the computing system to perform a transformation on the retrieved word by:

selecting a subcorpus of the corpus of words based on the length value;

determining a quotient of the distance divided by a number of words in the selected subcorpus; and

selecting the transformation based on the quotient.

19. The non-transitory computer-readable storage medium of claim **10**, wherein the instructions are further configured to cause the computing system to maintain a first subcorpus for words in the corpus of words of a first language and a second subcorpus for words in the corpus of words of a second language.

20. The non-transitory computer-readable storage medium of claim **10**, wherein the retrieving the word within the corpus of includes indexing the corpus of words using a remainder based on dividing the distance value by a number of words in the corpus of words.

21. The non-transitory computer-readable storage medium of claim **10**, wherein the instructions are further configured to cause the computing system to:

select a subcorpus from the corpus of words based on the length value;

select an index of transformations from the at least one memory device based on the length value; and

perform a transformation on the retrieved word, the transformation being selected from the selected index of transformations.

22. The non-transitory computer-readable storage medium of claim **21**, wherein:

the retrieved word is selected based on a remainder determined by dividing the distance value by a number of words in the subcorpus; and

the transformation is selected by indexing the selected index of transformations based on a quotient determined by dividing the distance value by the number of words in the subcorpus.

23. The non-transitory computer-readable storage medium of claim **10**, wherein the corpus of words stores the words in an order based on their frequencies.

24. A non-transitory computer-readable storage medium comprising instructions stored thereon that, when executed by at least one processor, are configured to cause a computing system to compress data by:

determining whether a sequence of characters matches a word included in a corpus of words or matches a transformed version of the word, the corpus of words being stored in at least one memory device and the transformation performed on the word being stored in the at least one memory device;

if the sequence of characters does not match the word included in the corpus of words and is not one transformation away from the word, encoding the sequence of characters as a sequence of codewords;

if the sequence of characters matches the word included in the corpus of words, encoding the sequence of characters with a reference to the word; and

if the sequence of characters matches the transformed version of the word, encoding the sequence of characters with a reference to the word and a reference to the transformation;

the reference to the word and the reference to the transformation including a number based on multiplying a number of words in a corpus by a number associated with the transformation and adding a number associated with the word.

25. The non-transitory computer-readable storage medium of claim **24**, wherein the instructions are further configured to cause the computing system to:

determine whether the sequence of characters matches a previously encoded sequence of characters; and

if the sequence of characters does match the previously encoded sequence of characters, encode the sequence of characters with a reference to the previously encoded sequence of characters.

* * * * *